# THE HARDWOOD ECOSYSTEM EXPERIMENT

## OBJECTIVES AND EARLY RESPONSES TO TREATMENT

INDIANA DEPARTMENT OF NATURAL RESOURCES
FOREST STEWARDSHIP COORDINATING COMMITTEE MEETING

MARTINSVILLE, INDIANA

24 SEPTEMBER 2013

Andy Meier, Project Coordinator

HEE Hardwood Ecosystem Experiment

1. Project background
2. Experimental design
3. Initial results
4. Future directions

# Outline

# HEE Background

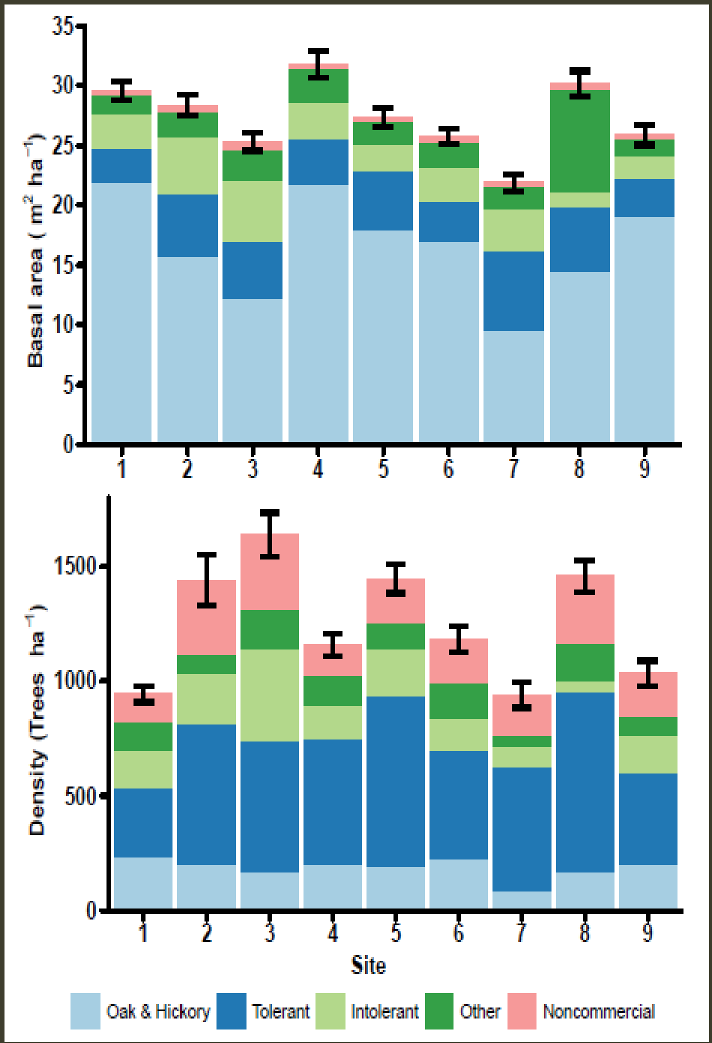


R. Kalb

- For the past few decades, there has been growing concern about the regeneration of oak-dominated forests in Indiana

# HEE Background






Source: Saunders and Arsenault 2013

- Overstory dominated by oaks and hickories
- Pole and regeneration layers dominated by shade tolerants, mainly American beech, sugar maple and red maple

# HEE Background



## But . . .

- Forest management in Indiana has not generally been successful in regenerating oak on the best sites
- Public support for intensive silviculture on public lands is often lacking
- Little local data was available on the impact of management alternatives on other ecosystem functions

R. Kalb

## So . . .

- The Hardwood Ecosystem Experiment (HEE) was initiated in 2006 with four main objectives:

B. MacGowan

# HEE Objectives



1. Develop silvicultural systems that maintain oak dominated forests
2. Determine the impacts of these systems of ecological communities
3. Determine the impacts of these systems on human communities
4. Develop tools to engage the public regarding forest management and ecosystem health

R. Kalb

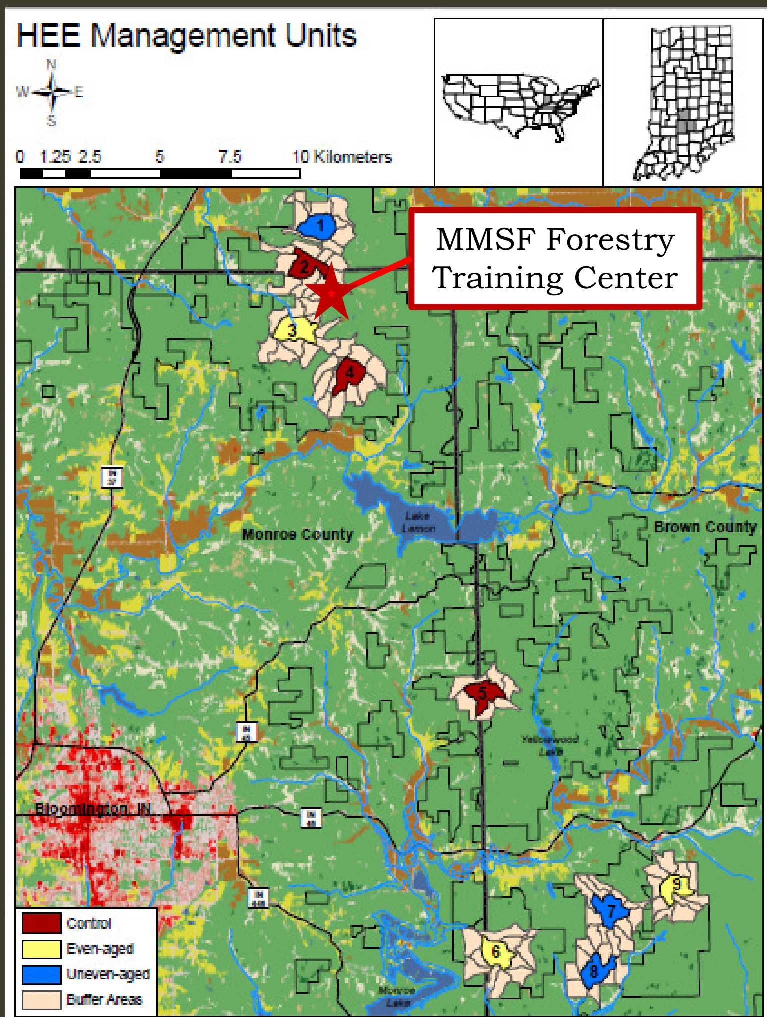
Source: Kalb and Mycroft 2013




# HEE Design

# Study sites






Source: Kalb and Mycroft 2013

- Nine study sites on Morgan-Monroe and Yellowwood State Forests
  - Each unit includes a research core (190-270 ac) and buffer area (540-975 ac)
  - 20 miles between nothernmost and southernmost units

A. Meier

# Treatment schedule

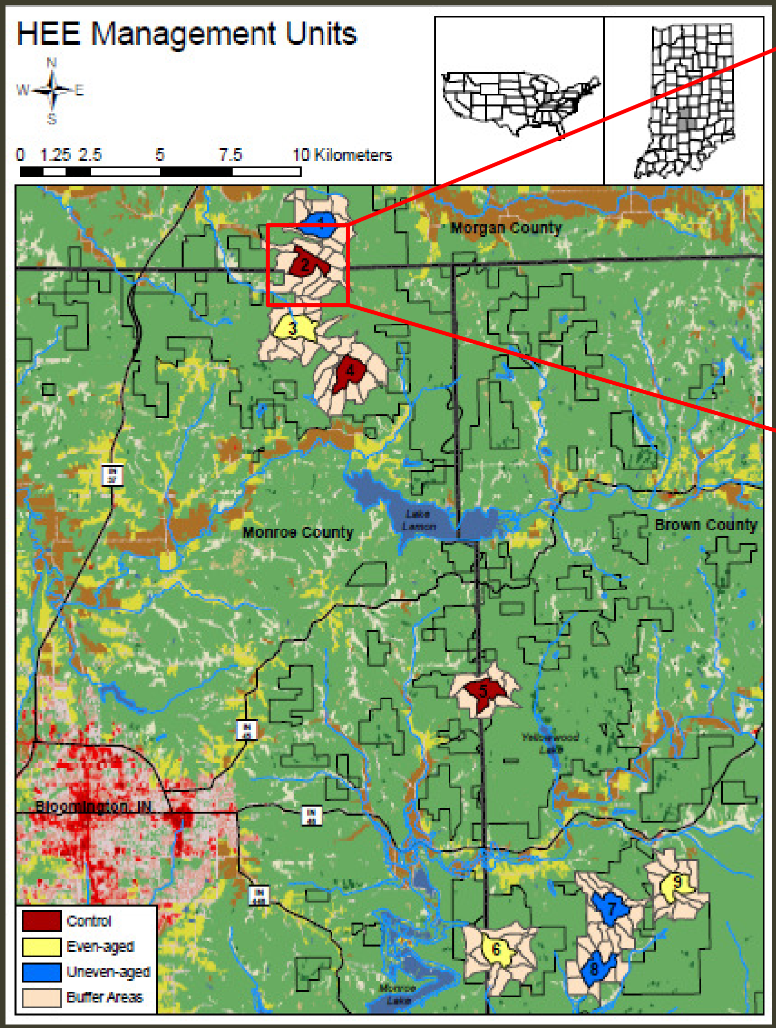


- 2006
  - Baseline data collection begins
- 2008-09
  - First harvest cycle
- 2028
  - Next scheduled harvest cycle
  - Every 20 years until 2108


# HEE Treatments

# Control units



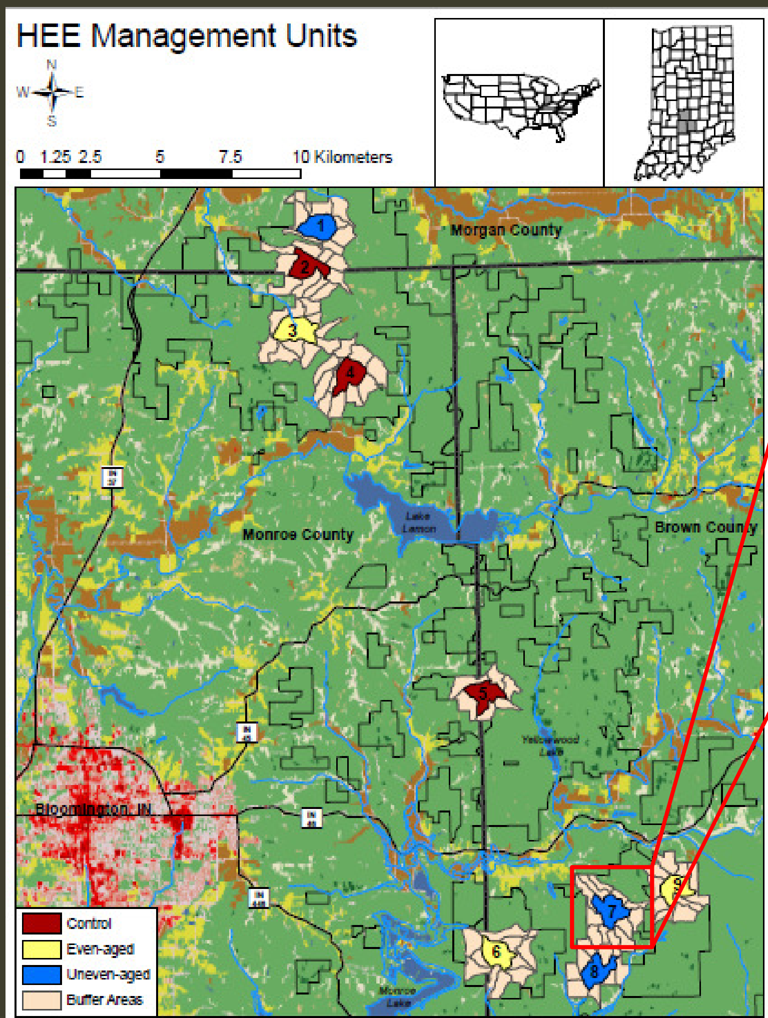



- No harvesting

Source: Kalb and Mycroft 2013

# Uneven-aged units



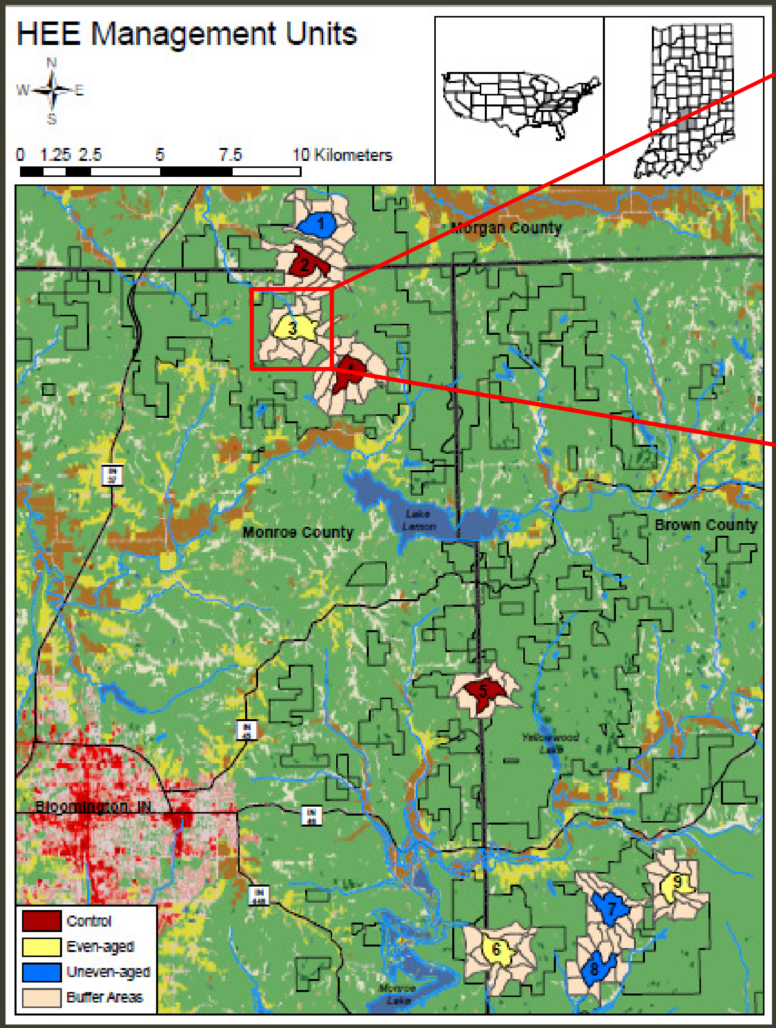



- Two each of 5 and 3 ac patch cuts (1st cycle only)
- Four 1 ac patch cuts (1st cycle only)
- Single tree-selection in matrix (all cycles)

Source: Kalb and Mycroft 2013

# Even-aged units

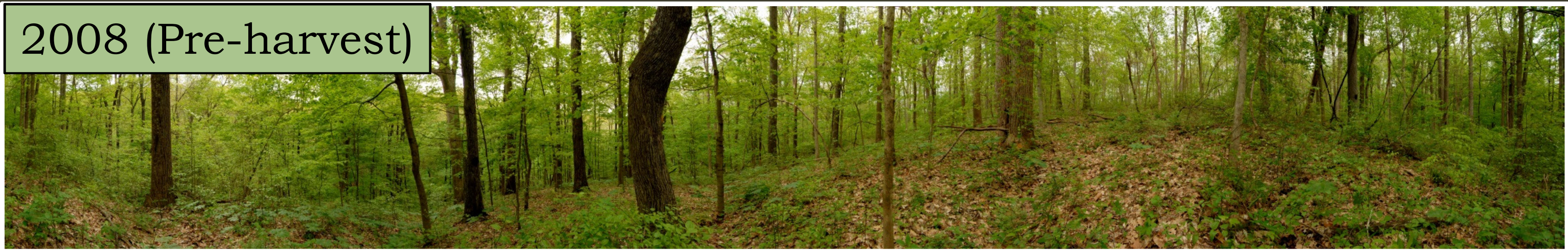





- Two clearcuts and two shelterwoods 8-10 ac each per treatment cycle
- Matrix unmanaged until next round of treatments

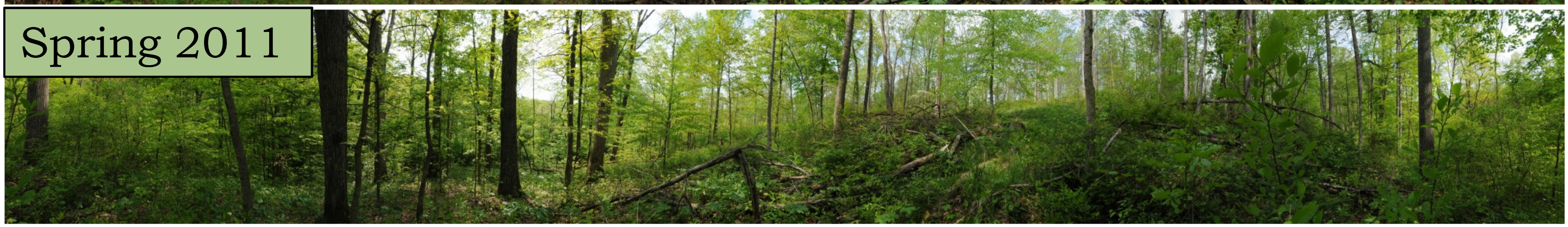
Source: Kalb and Mycroft 2013

# Single-tree selection, MMSF



2008 (Pre-harvest)

Spring 2009



Spring 2011

Spring 2013

Photos: John Maxwell, Indiana DNR

# 3-ac patch cut, MMSF

2008 (Pre-harvest)

Spring 2009

Spring 2011

Spring 2013

Photos: John Maxwell, Indiana DNR

# 10-ac clearcut, MMSF

2008
(Pre-harvest)

Spring 2009

Spring 2011

Spring 2013

Photos: John Maxwell,
Indiana DNR




# HEE Studies

# Stand Level Studies



| | Start Date | Inventories completed |
|---|---|---|
| **Woodland Salamanders** | 2007 | 6 |
| Bats | 2006 | 7 |
| Wood-boring Beetles | 2006 | 6 |
| Oak Mast Dynamics | 2006 | 7 |
| Small Mammals | 2007 | 6 |
| Deer exclosures | 2010 | 2+ |

# Landscape Level Studies



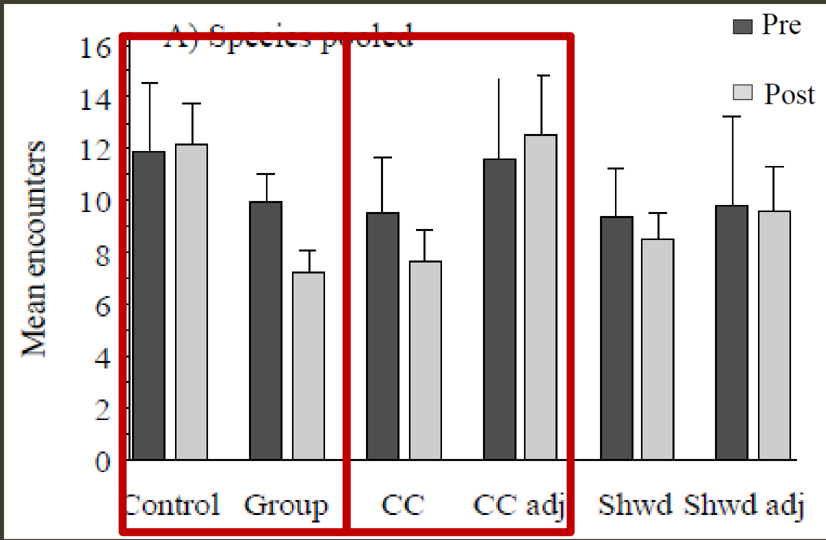
| | Start Date | Inventories completed |
|---|---|---|
| **Breeding Birds** | 2006 | 7 |
| Cerulean Warblers | 2007 | 6 |
| Timber Rattlesnakes | 2007 | 5 |
| Eastern Box Turtles | 2007 | 4 |
| Owls | 2009 | 4 |
| **Vegetation** | 2008 | 1.5 |
| Social Science | 2007 | 2 |

# Salamanders



R. N. Williams, R.N. Chapman, Purdue University

- Clearcuts had significantly fewer encounters than areas adjacent to the clearcuts
- Patch cuts had significantly fewer encounters than controls
- Slope and temperature also significant factors
- Clearcuts and patch cuts still appear to have fewer salamanders




MacNeil 2011

B. Kalb

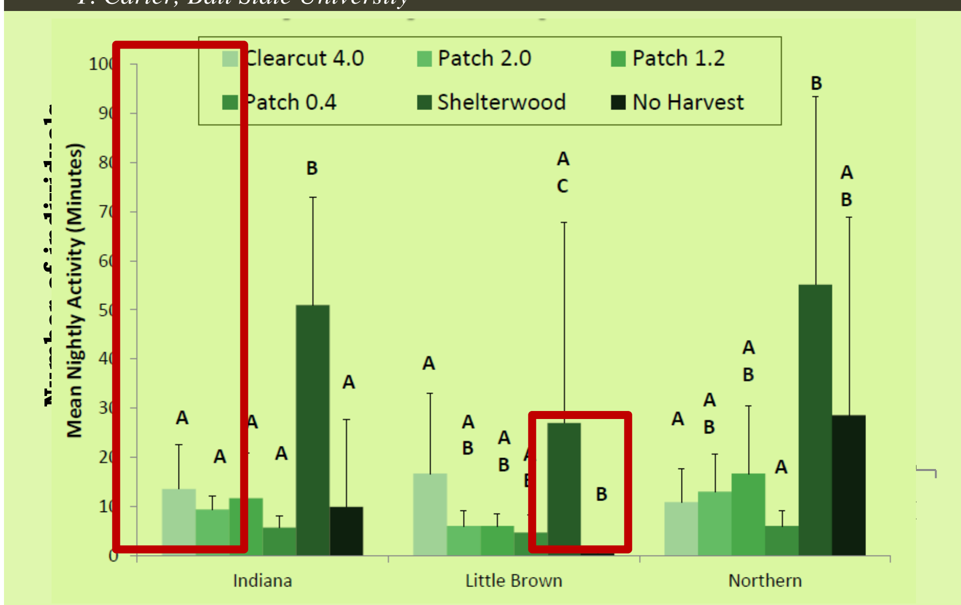
Source: MacNeil 2011, MacNeil et al. 2013

# Bats



J. O'Keefe, Indiana State University and T. Carter, Ball State University

*T. Carter, Ball State University*




Source: Sheets et al. 2013, HEE Annual Reports 2010-13

Source: Nolder and Duchamp 2013

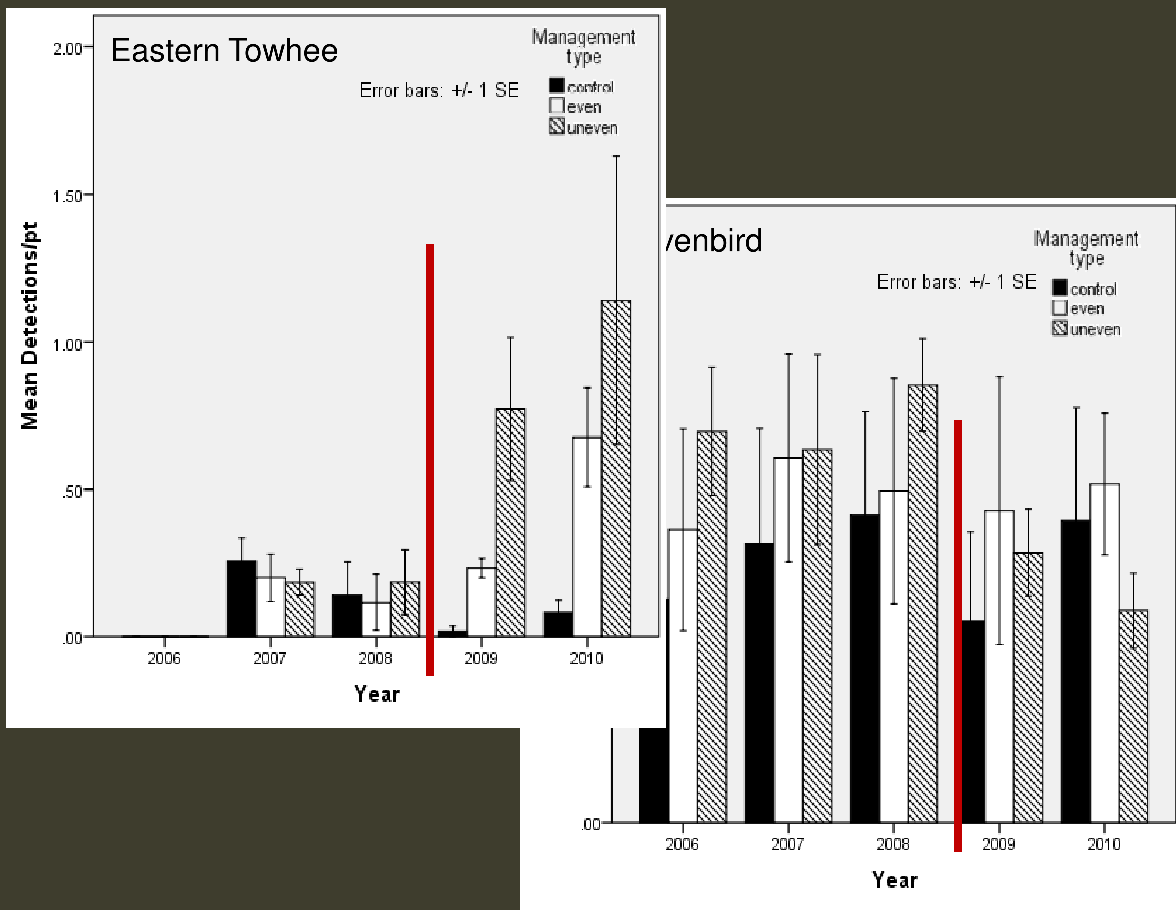
**Studies**

- Acoustics, mist-netting and radio-telemetry
- Northern long-eared bat (MYSE) most common on HEE sites
- Endangered Indiana bat (MYSO) present but uncommon
- Bat activity varies in response to treatment depending on species
- No radio-telemetry data yet, but provide invaluable data on northern long-eared bat habitat needs

# Breeding birds



J. B. Dunning, Purdue University



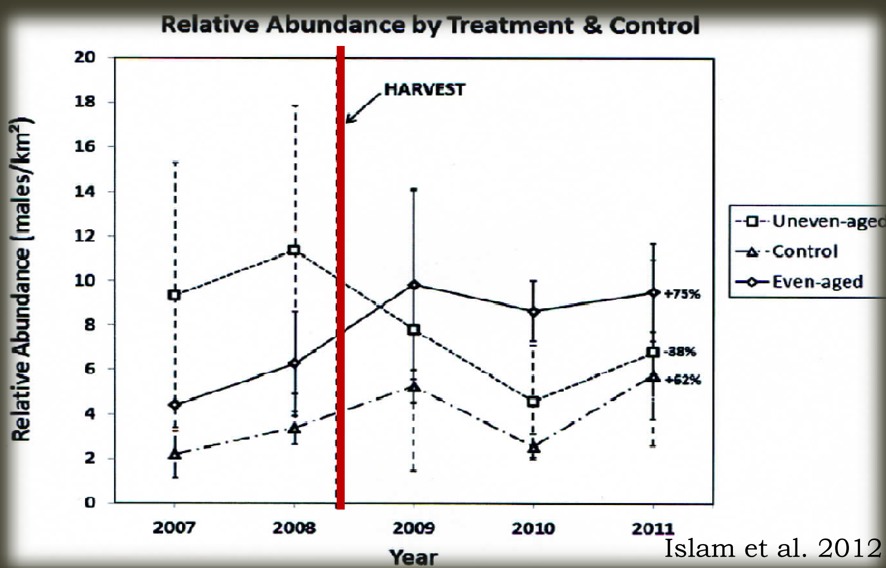

- Early-successional guild
  - All species except Brown-headed Cowbird increased in abundance
- Mature-forest guild
  - More variable response
  - Either positive or non-significant response
  - No significant negative effects

Source: Malloy 2012, Malloy and Dunning 2013

# Cerulean Warblers



K. Islam, Ball State University




Islam et al. 2012

- Increased number of detections in even-aged and control units
- Decreased number of detections in uneven-aged units
- Nest success was highest in control units and lowest in uneven-aged units
- Territory size appears to be smaller near clearcuts

Source: Dibala 2012, Islam et al. 2012

# Owls



R.K. Swihart and J.B. Dunning, Purdue University

**Project design**

- Citizen-science: almost all data is collected by volunteers
- Data analyzed for an undergraduate research project
- Manuscript currently in preparation written by undergraduate researchers

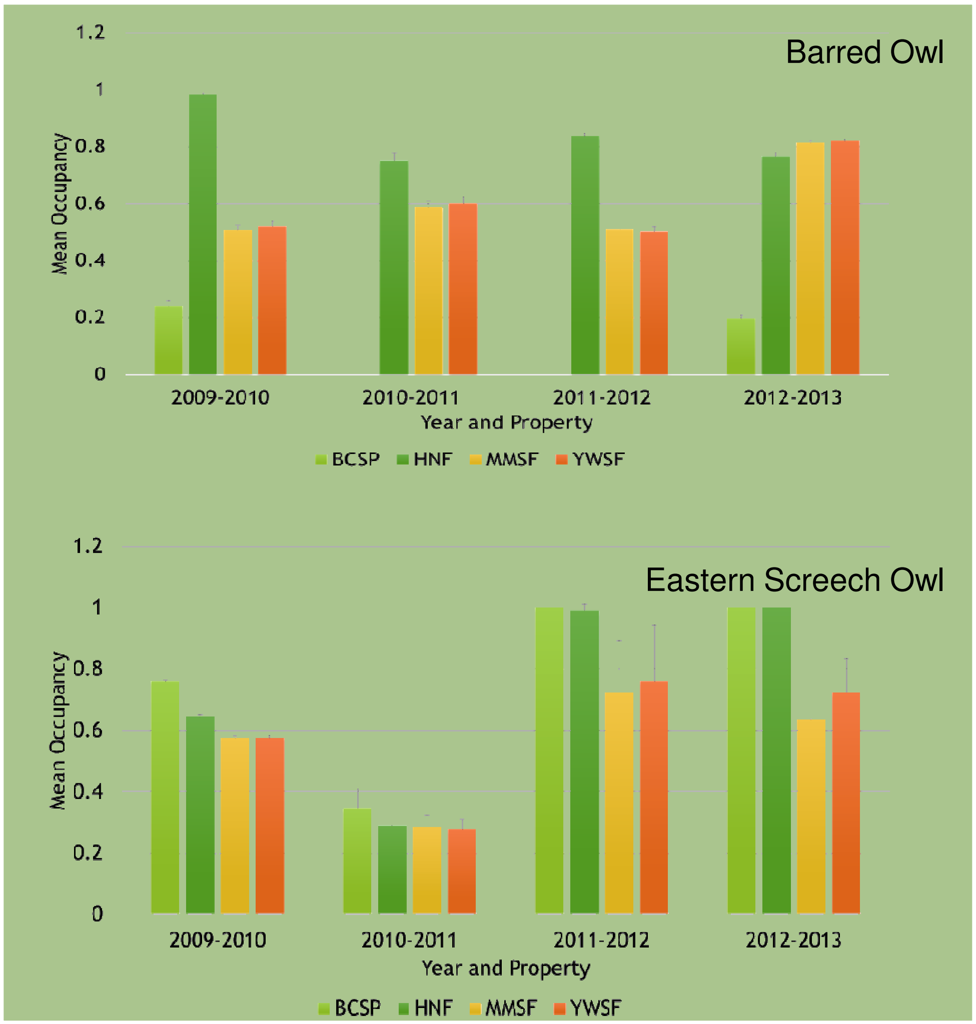
J. Moore

K. DeCosta

# Owls



R.K. Swihart and J.B. Dunning, Purdue University




- No consistent responses across properties
- Low Barred Owl occupancy in Brown County State Park potentially a result of high human activity
- Eastern Screech Owl had a higher rate of occupancy when Barred Owls had lower rates
- But, how does this change over time?

Source: Leonard et al., in prep

# Additional HEE Studies



| | Start Date | Inventories completed |
|---|---|---|
| Owls | 2009 | 4 |
| Deer exclosures | 2010 | 2+ |
| Nightjar surveys | 2009 | 2 |
| Ruffed Grouse surveys | 2009 | 2 |
| Year-round bird surveys | 2009 | 2 |
| American Woodcock surveys | 2012 | 1 |
| Epicormic branching | 2011 | 1 |

# HEE Summary to Date

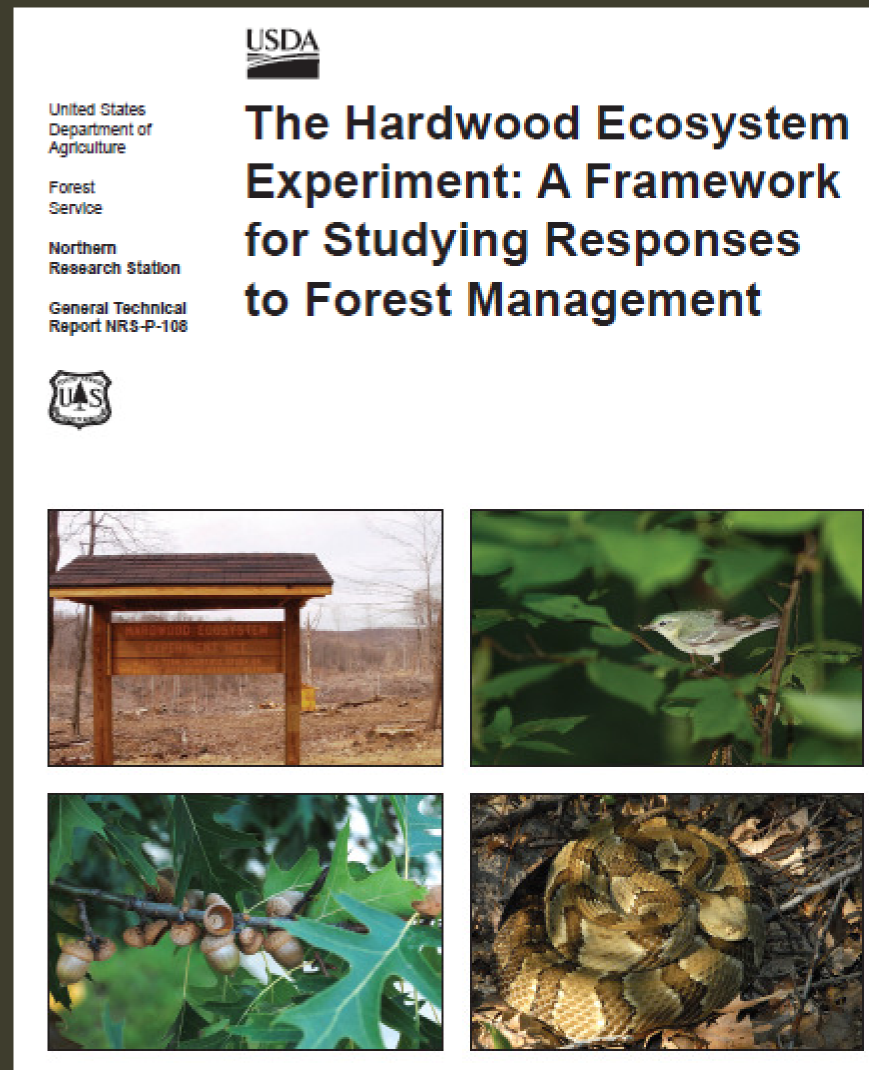


25 peer-reviewed journal publications in press or in print, 350 page US-Forest Service General Technical Report

Almost 20 principal investigators from 7 universities

22 graduate students have conducted graduate research on the HEE, more than 130 undergraduate and post-baccalaureate technicians and researchers

Over 75 presentations to diverse audiences, from school groups to scientific meetings


USDA

United States Department of Agriculture

Forest Service

Northern Research Station

General Technical Report NRS-P-108

The Hardwood Ecosystem Experiment: A Framework for Studying Responses to Forest Management

# Future research directions



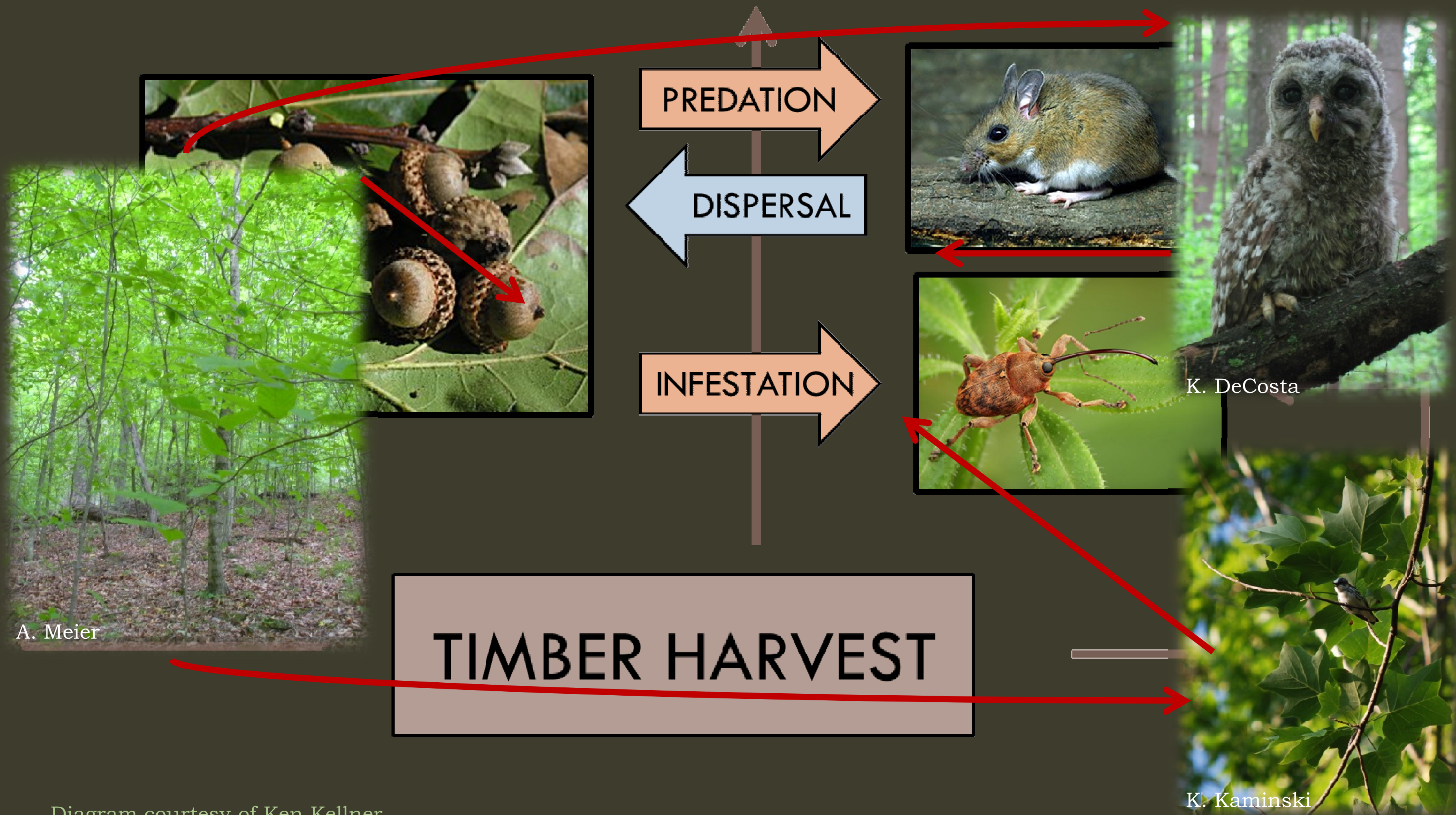
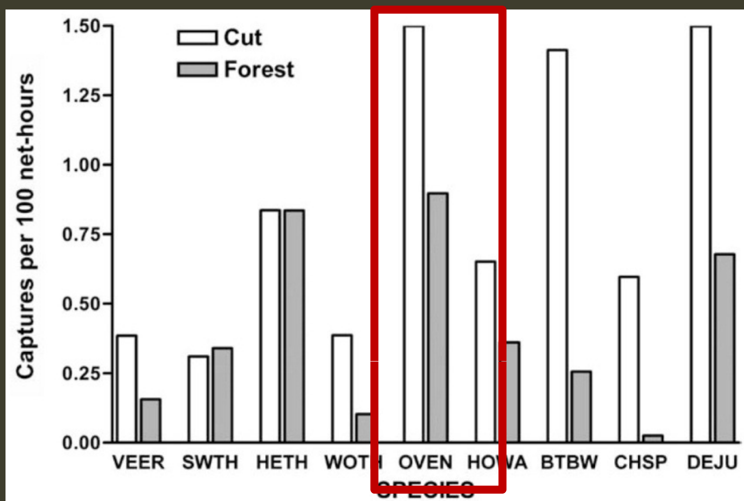
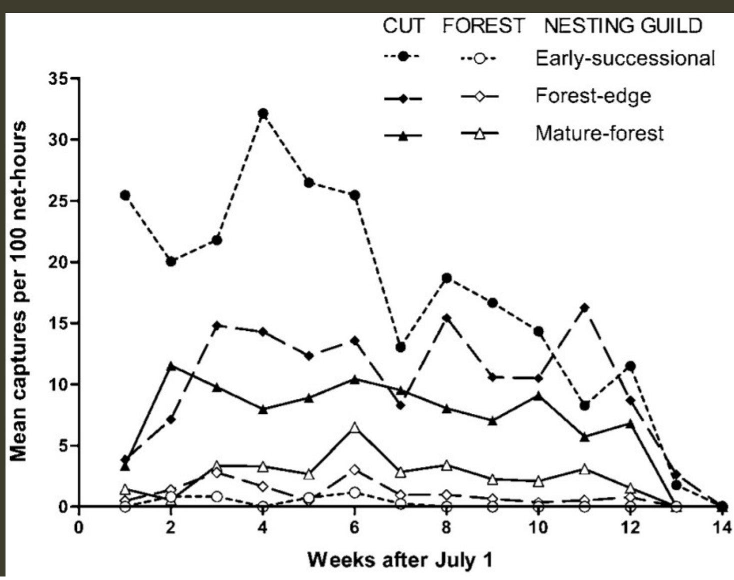



Diagram courtesy of Ken Kellner

# Future research directions





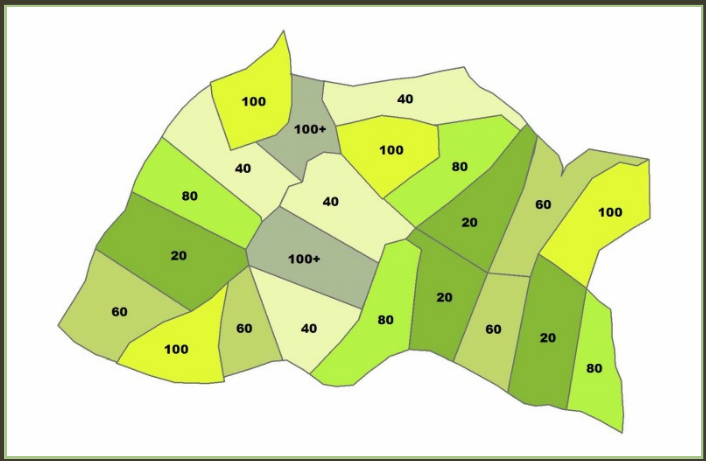

**Presence vs. fitness**

- We have seen changes in abundances of different species in response to forest management, but . . .
- Do these changes reflect actual differences in the health of populations?
- How do these population responses change over time?

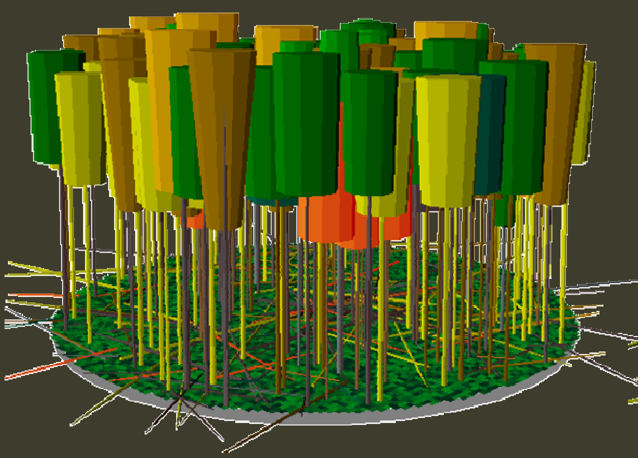
Source: Stoleson 2013

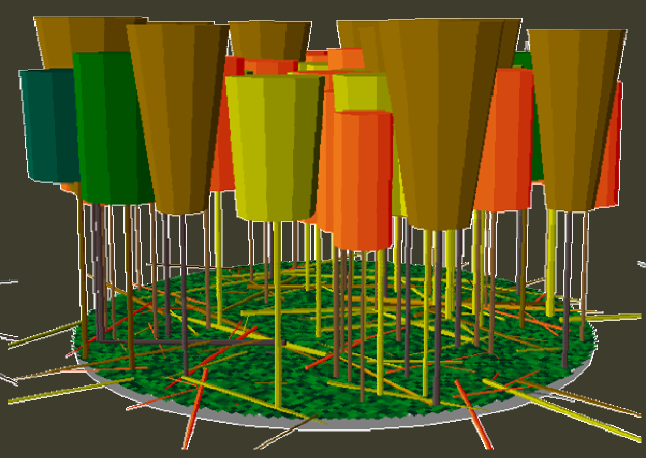
# Stand Characteristics in 2100

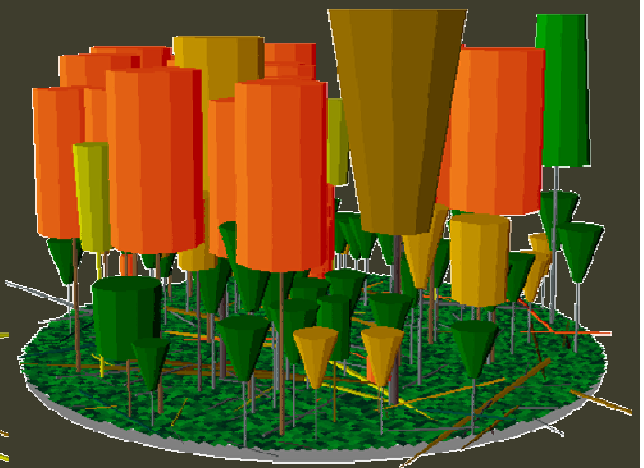





- In even-aged units, uniform mix of 0-100 year old stands and greatest component of intolerants
- In control units, 200+ year old trees with increasing rate of natural mortality
- In uneven-aged units, trees generally 0-100 years old with accelerated dominance by tolerants







# Future research directions



**Development of advance oak regeneration**

- We would like to see higher levels of oak seedling establishment and recruitement.
- We suspect that this is largely due to a low number of oak seedlings and saplings prior to harvest.
- What effect would multiple, low-intensity prescribed burns prior to treatment have on
  - Oak establishment?
  - Residual tree quality?
- Are even-aged treatments necessary for oak establishment?

# HEE Partners



Forestry DNR INDIANA

INDIANA STATE UNIVERSITY
Center for North American Bat Research and Conservation

PURDUE UNIVERSITY
1913 - 2013
Forestry & Natural Resources

INDIANA UNIVERSITY

Drake UNIVERSITY

Entomology
Discovery • Learning • Engagement
Department of Entomology, Purdue University

BALL STATE UNIVERSITY

# References



Dibala, R. 2012. Population response of a declining songbird to silviculture: how Cerulean Warbler (Setophaga cerulea) territory size and settlement patterns fare in the face of forest disturbance. Master of Biology Thesis. Ball State University, Muncie, IN.

Haulton, G.S. 2013. Past is prologue: a synthesis of state forest management activities and Hardwood Ecosystem Experiment pre-treatment results. Gen. Tech. Rep. NRS-P-108. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [CD ROM] pp. 339-349.

Islam, K., J.Wagner, R.Dibala, M.M.MacNeil, K.J.Kaminski and L.P.Young. 2012. Cerulean Warbler (Setophaga cerulea) response to changes in forest structure in Indiana. Ornitologia Neotropical 23: 335-341

MacNeil, J.E. 2011. The effects of forest management on terrestrial salamanders. Master of Science Thesis. Purdue University, West Lafayette, Indiana.

MacNeil, J.E., B.J.MacGowan, A.F.Currylow and R.N.Williams. Published. Forest management for reptiles and amphibians: a technical guide for the Midwest FNR-480-W, Purdue University Extension, West Lafayette, Indiana, USA

Malloy, M.C. 2012. Effects of forest management on breeding bird populations on mixed deciduous forests of southern Indiana. Master of Science Thesis. Purdue University, West Lafayette, Indiana.

Malloy, M.C. and J.B.Dunning. 2013. Breeding bird communities of the Hardwood Ecosystem Experiment. Gen. Tech. Rep. NRS-P-108. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [CD ROM] pp. 126-141.

Saunders, M.R. and J.E.Arsenault. 2013. Pre-treatment analysis of woody vegetation composition and structure on the Hardwood Ecosystem Experiment research units. Gen. Tech. Rep. NRS-P-108. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [CD ROM] pp. 96-125.

Saunders, M.R. and R.K.Swihart. 2013. Science in the Hardwood Ecosystem Experiment: accomplishments and the road ahead. Gen. Tech. Rep. NRS-P-108. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. [CD ROM] pp. 315-332.

Summerville, K.S. 2013. Forest lepidopteran communities are more resilient to shelterwood harvest compared intensive logging regimes. Ecological Applications. http://dx.doi.org/10.1890/12-0639.1

# Thank you!



Volume 6, Issue 1

Spring/Summer 2013

Hardwood Ecosystem Experiment

THE HEE UPDATE

http://HEEForestStudy.org

Andy Meier, Project Coordinator | 765-494-1472 | meiera@purdue.edu

## HEE GENERAL TECHNICAL REPORT PUBLISHED

After many years of hard work, the Hardwood Ecosystem Experiment is proud to announce the release of "The Hardwood Ecosystem Experiment: A Framework for Studying Responses to Forest Management." This compendium of HEE data prior to timber harvesting in 2008-09 was published by the Northern Research Station of the USDA-Forest Service as General Technical Report NRS-P-108. All manuscripts in the document were reviewed by at least two anonymous scientists prior to publication.

The Hardwood Ecosystem Experiment: A Framework for Studying Responses to Forest Management

The entire document spans a total of 350 pages and includes 21 chapters describing baseline conditions on all of the HEE sites before the initiation of harvesting treatments. It is intended to be a reference for future researchers as well as a resource for the general public. The entire manuscript is available free of charge online at http://www.nrs.fs.fed.us/pubs/42882. No printed copies are available, but requests for CD-ROMs can also be made at this website.

## North American Forest Ecology Workshop

The 9th North American Forest Ecology Workshop (NAFEW) was held in Bloomington, Indiana from June 16-20, 2013. Dr. Mike Saunders, Purdue University associate professor of silviculture and HEE Executive Committee member, was the chair for the workshop, so the HEE was a central component of the program. One full-day field tour of the HEE sites and nearby Brown County State Park was scheduled which was attended by more than 20 scientists and natural resource managers from across North America. In addition, a session of oral presentations titled "Long-term Experiments in Managed Central Hardwood Forests" was organized along with the Missouri Ozark Forest Ecosystem Project (MOFEP) to highlight findings from these two studies.

The workshop was well attended, well received, and provided many opportunities to showcase the valuable work being conducted on the HEE. Many thanks are due to the researchers who took the time to present for the workshop. See http://nafew.org for the workshop agenda.

Ball State University graduate students Sasha Auer and Kevin Barnes presenting during the NAFEW HEE Field Tour

- To receive the HEE update newsletter (published twice a year) either,
  - Sign your name and email or mailing address on the sheet I am circulating
  - Send me an email, **meiera@purdue.edu** with the subject "HEE newsletter" requesting to be added to the distribution list

# HEE Background



- The HEE was initiated in 2006 to address these issues

T. Carter

K. Kaminski

B. MacGowan

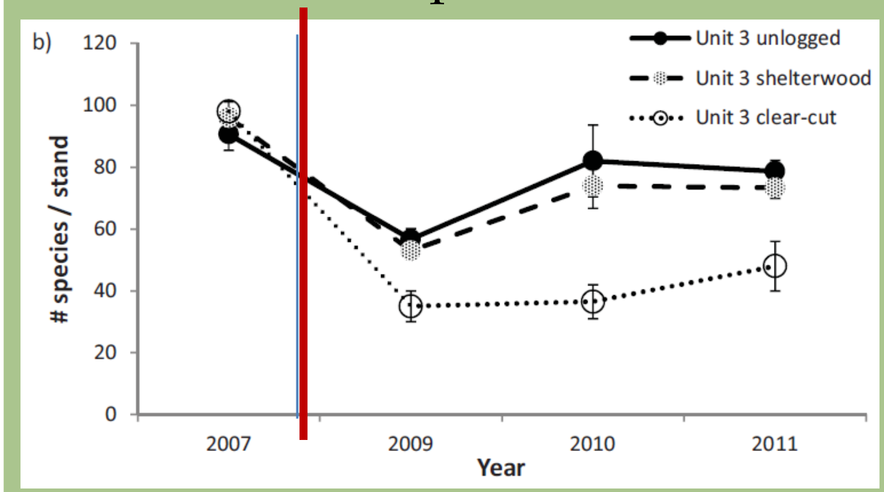
- Funding agency
  - Indiana Department of Natural Resources – Division of Forestry
- Location
  - Morgan-Monroe and Yellowwood State Forests in southern Indiana
  - Threatened and endangered species

# Lepidoptera



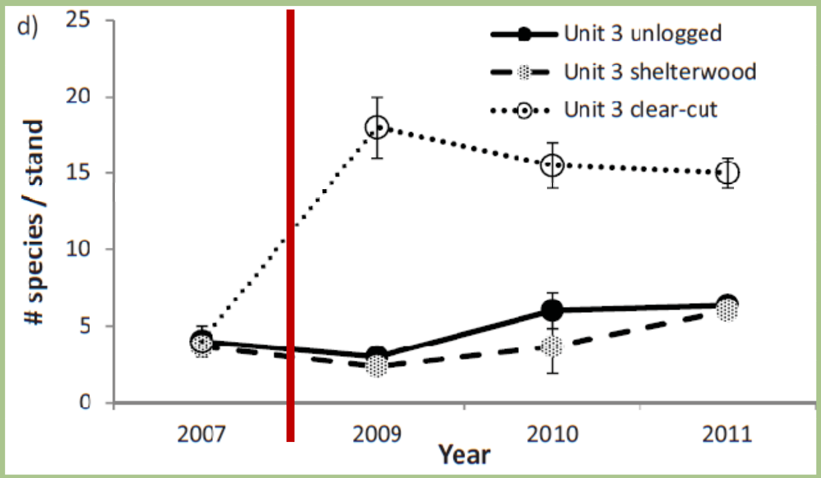
K. Summerville, Drake University

## All species




- Overall decrease in species diversity in clearcuts
- Patch cut species diversity rebounding
- Total number of individuals shows same pattern

## Herbaceous feeders



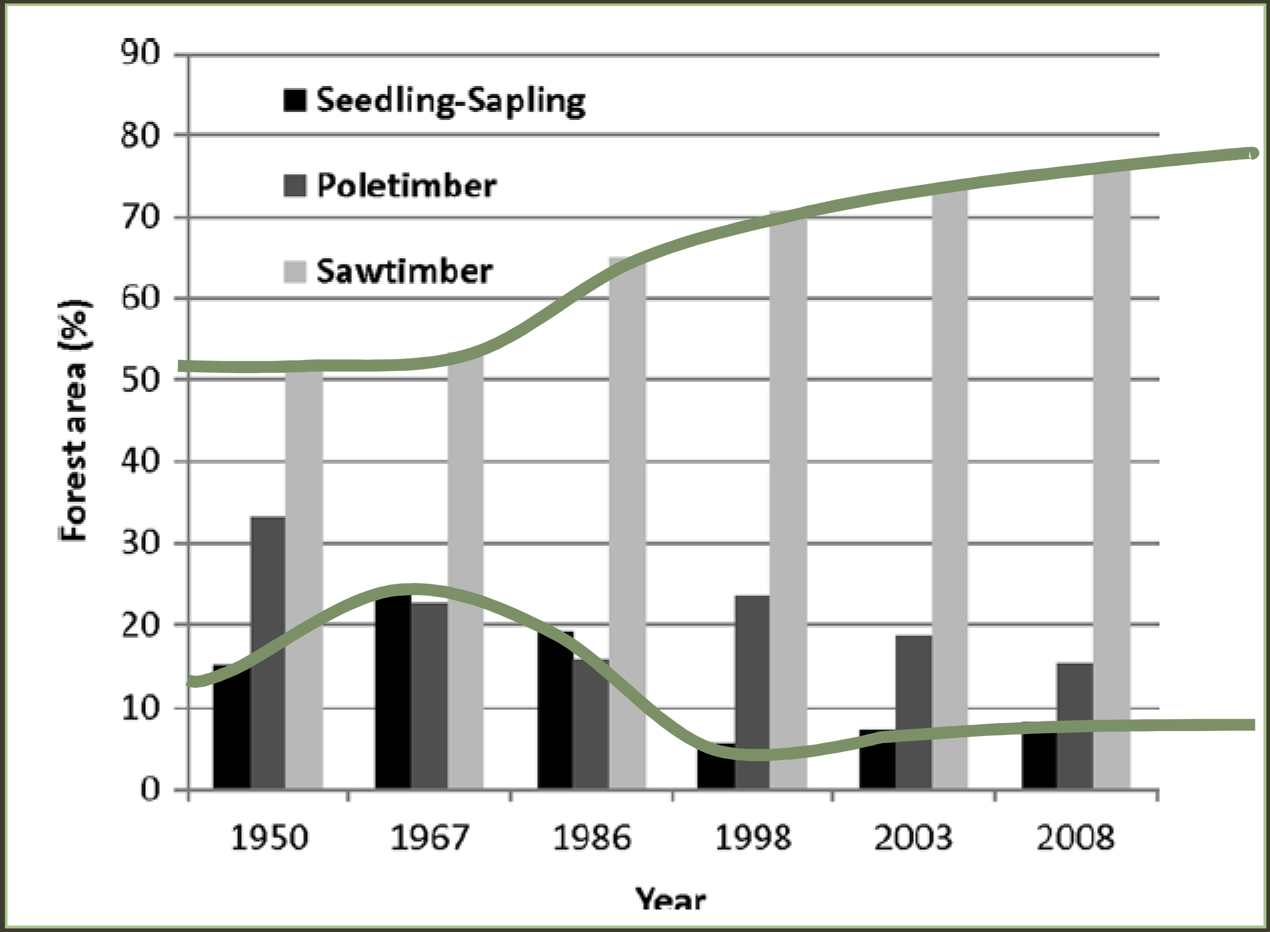

- Responses differ by functional traits
- Substantial increase in diversity of herbaceous feeders in clearcuts
- Pollinator diversity also higher in clearcuts

Source: Summerville 2013

# HEE Background



- Age structure of Central Hardwood Forests




Shifley and Thompson 2011

# HEE Background



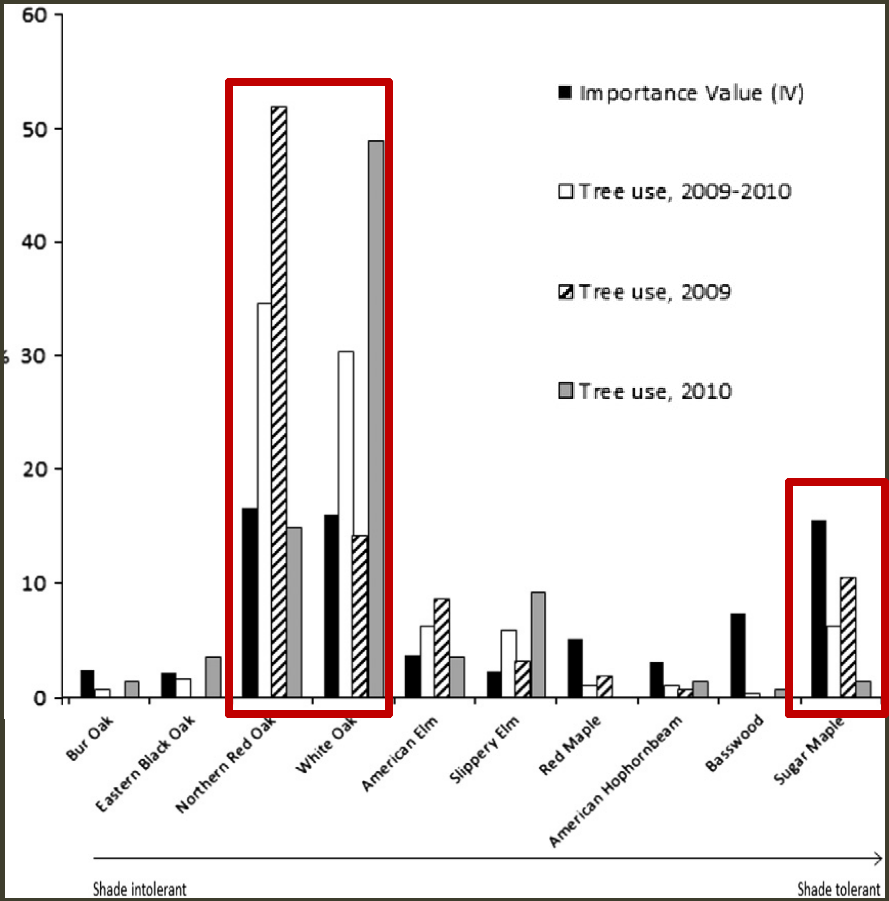
- How do we regenerate oak-hickory ecosystems in Indiana?

R. Kalb

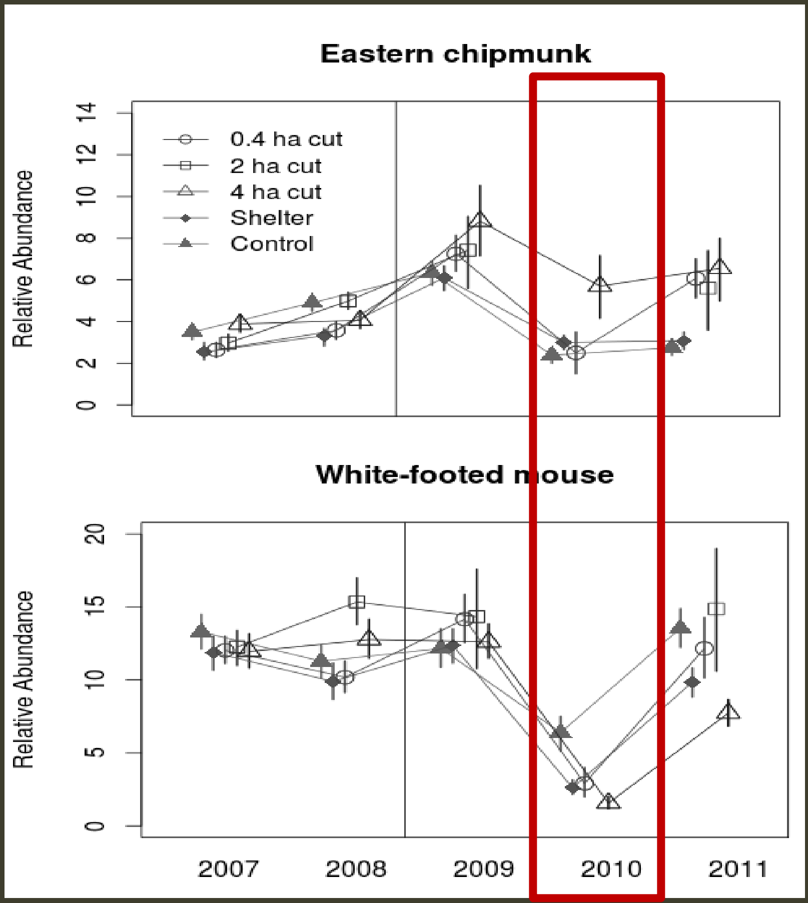
- Context:
  - Altered disturbance regimes
  - Wildlife habitat

# HEE Background






Source: Wood et al. 2012




Source: Kellner et al. 2013

# HEE Background



- How do we regenerate oak-hickory ecosystems in Indiana?

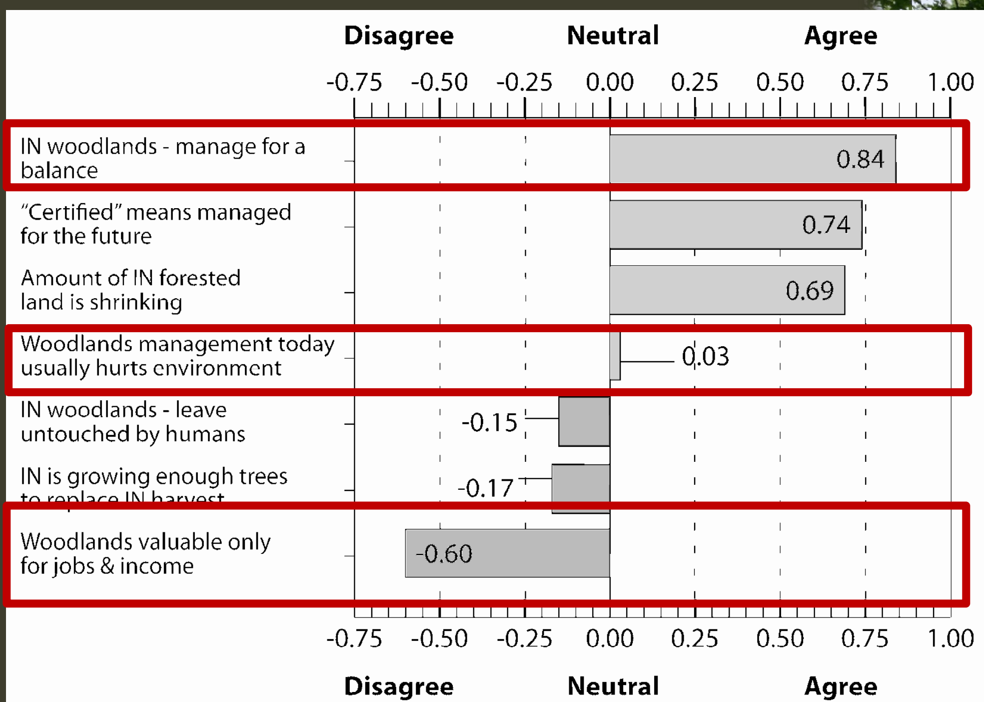
R. Kalb

- Context:
  - Altered disturbance regimes
  - Wildlife habitat
  - Public perception of resource management

# HEE Background



- Public perceptions of forest management




# HEE Objectives



- Develop even-aged and uneven-aged silvicultural systems that maintain oak dominated forest communities and landscapes

# HEE Objectives



- Determine both the positive and negative impacts of these systems on populations of herbaceous, avian, and terrestrial amphibian groups

A. Meier

R. Kalb

J. MacNeil

# HEE Objectives



- Determine the social and economic ramifications of these systems in both local and regional communities

D. Carlson

C. Mycroft

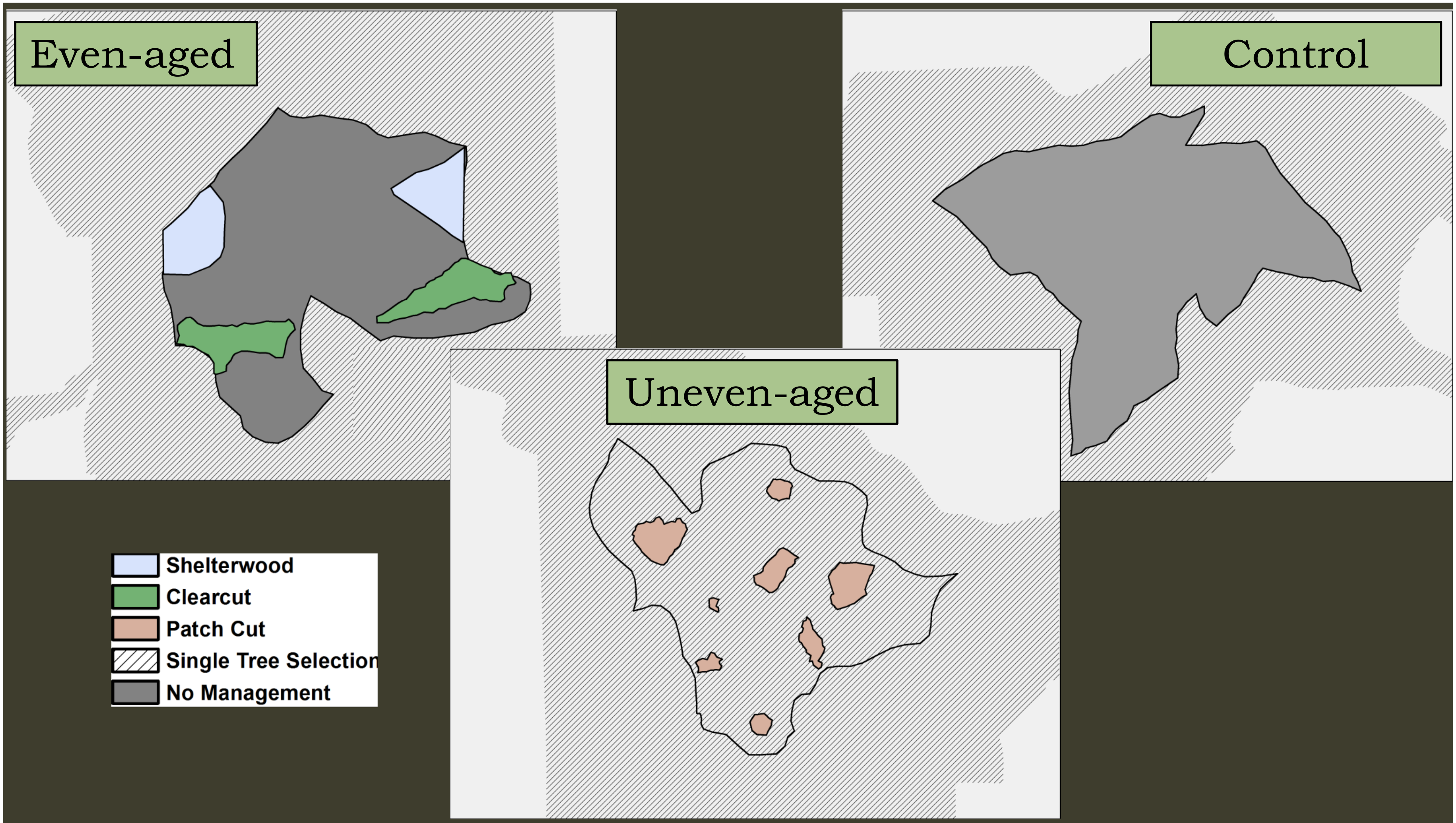
# HEE Objectives



- Provide demonstration sites and develop novel educational materials and techniques to engage the public concerning forest management

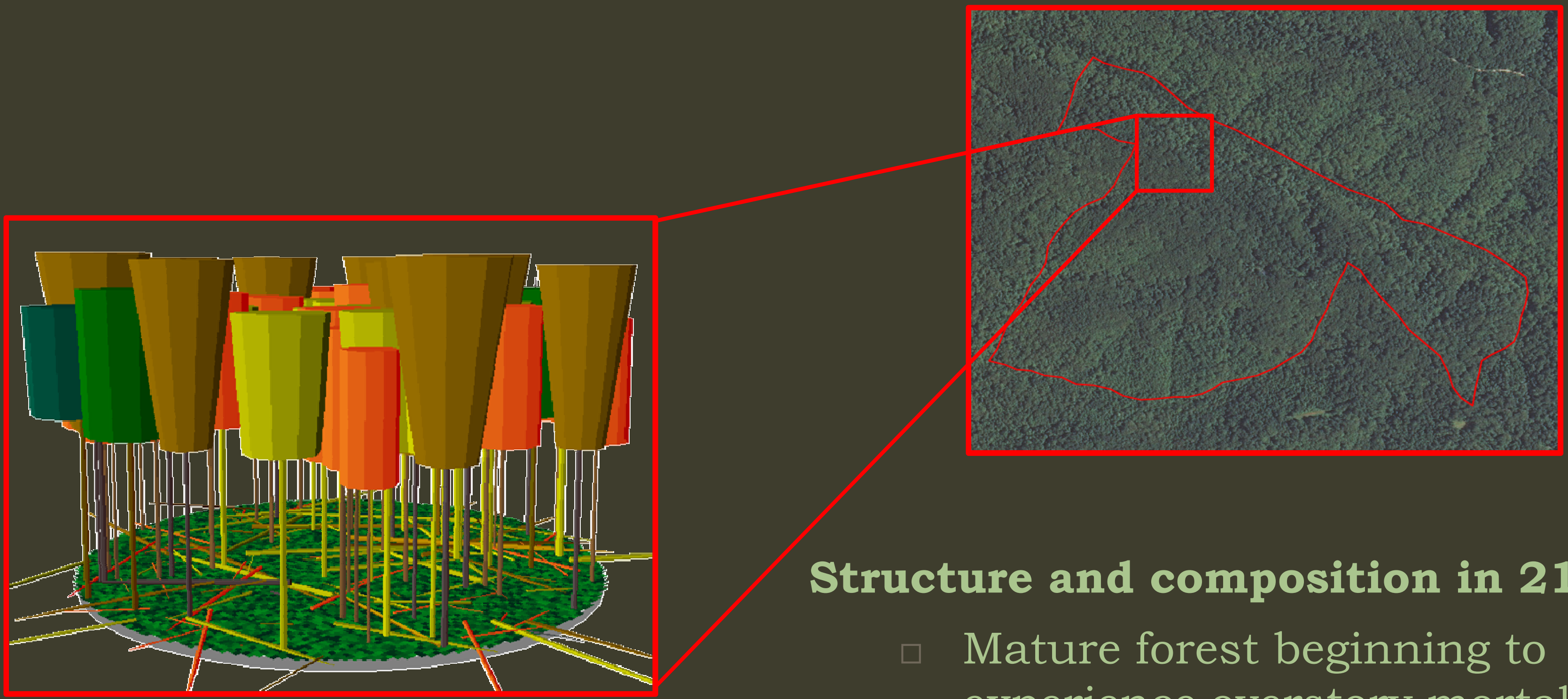

# 2008-09 Harvests





# Control units



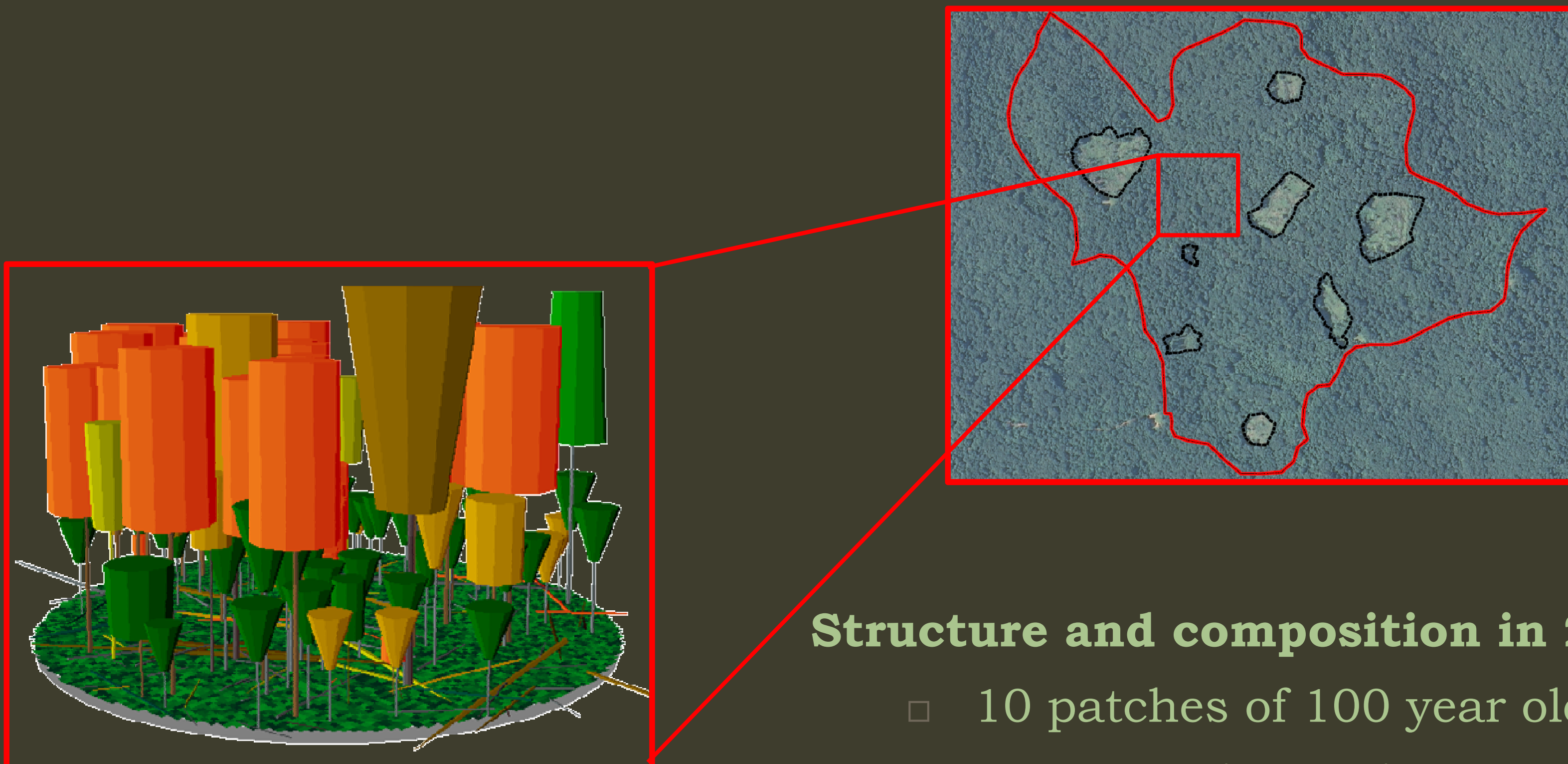


**Structure and composition in 2100**

- Mature forest beginning to experience overstory mortality
- Canopy dominated by 200+ year old oaks
- Strong maple-beech component in lower canopy

# Uneven-aged units





**Structure and composition in 2100**

- 10 patches of 100 year old trees
- Matrix multi-aged
- Multiple strata in the canopy
- Accelerated transition to maple/beech dominance

# Breeding birds



J. B. Dunning, Purdue University

## Early-successional

- Brown-headed Cowbird (*Molothrus ater*)
- Carolina Wren (*Thryothorus ludovicianus*)
- Indigo Bunting (*Passerina cyanea*)
- Eastern Towhee (*Pipilio erythrophthalmus*)

## Mature-forest

- Acadian Flycatcher (*Empidonax virescens*)
- Cerulean Warbler (*Setophaga cerulea*)
- Ovenbird (*Seiurus aurocapilla*)
- Red-eyed Vireo (*Vireo olivaceus*)
- Scarlet Tanager (*Piranga olivacea*)
- Worm-eating Warbler (*Helmitheros vermivorum*)
- Wood Thrush (*Hylocichla mustelina*)

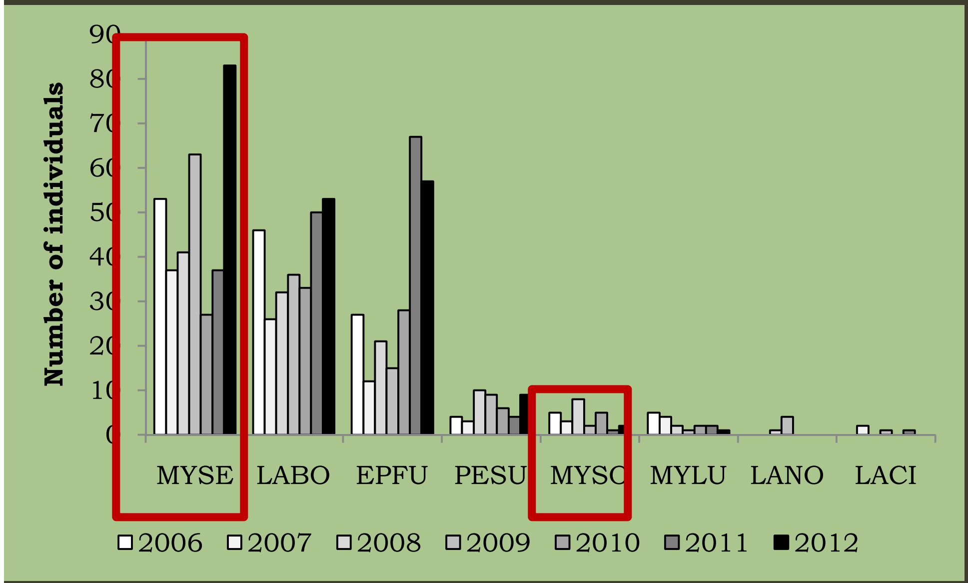
Source: Malloy 2012, Dunning and Malloy 2013

# Stand: Bats



J. O'Keefe, Indiana State University and T. Carter, Ball State University

*T. Carter, Ball State University*




Source: Sheets et al. 2013, HEE Annual Reports 2010-13

**Studies**

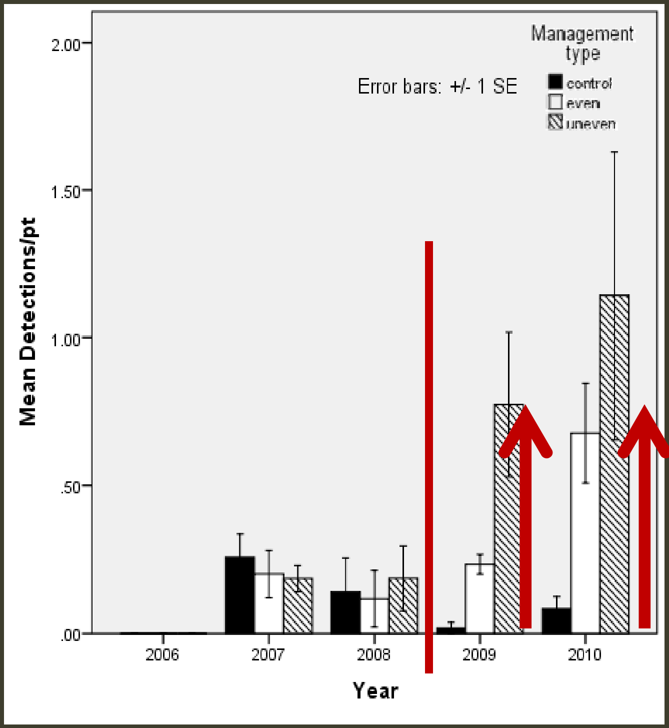
- Acoustics, mist-netting and radio-telemetry
- Northern long-eared bat (MYSE) most common on HEE sites
- Endangered Indiana bat (MYSO) present but uncommon

# Landscape vs. Stand

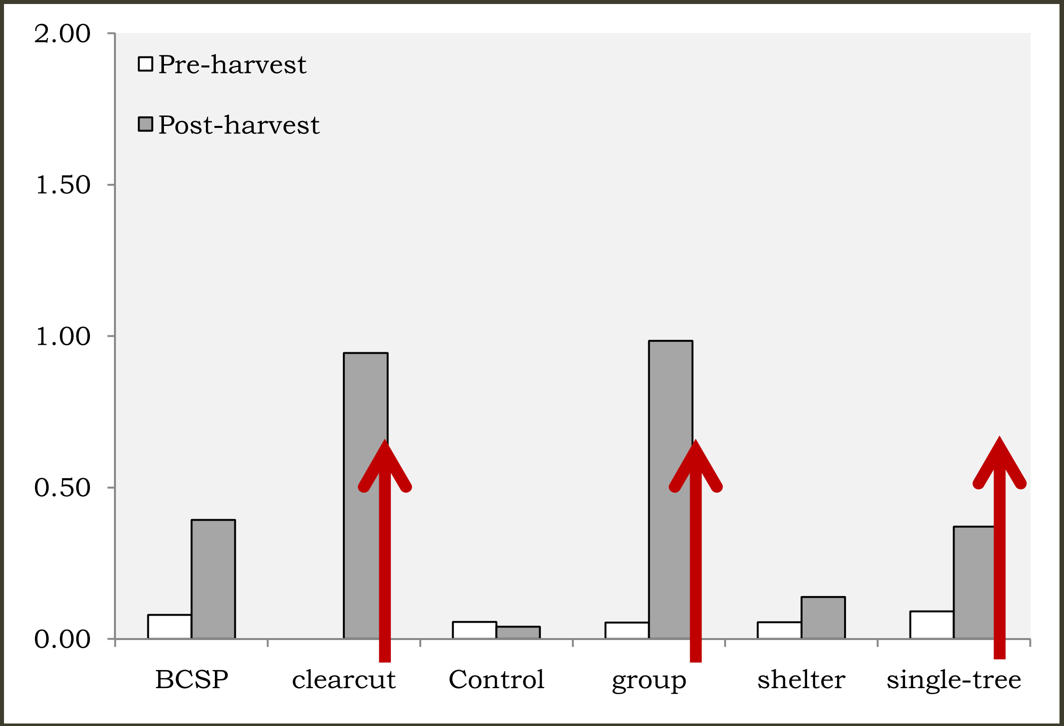


Case Study: Eastern Towhee

Landscape




Stand




Source: Malloy 2012, Malloy and Dunning 2013

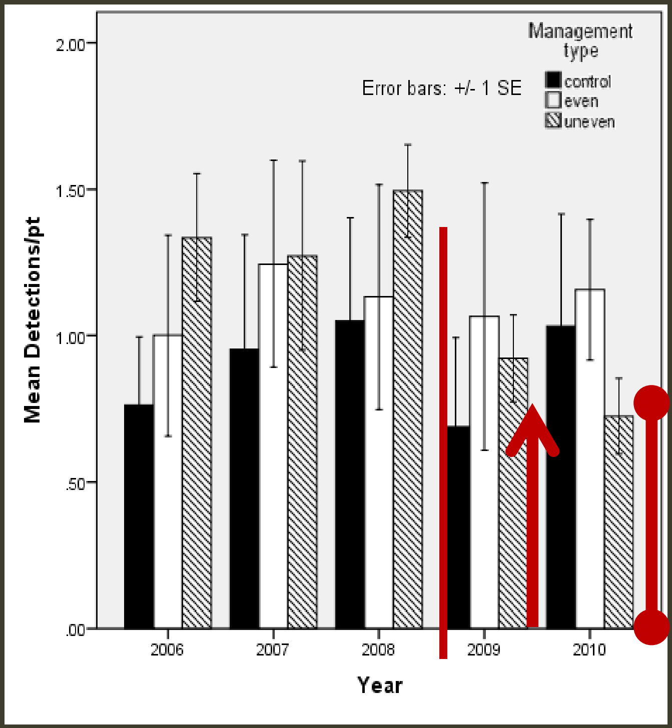
# Landscape vs. Stand

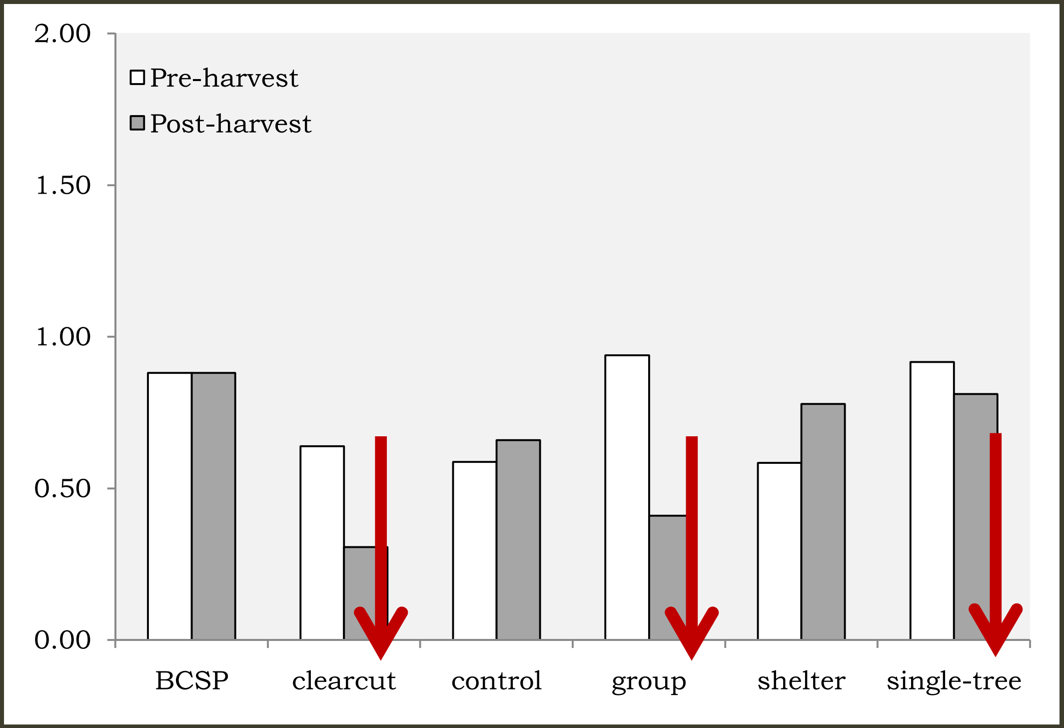


Case study: Ovenbirds

Landscape

Stand

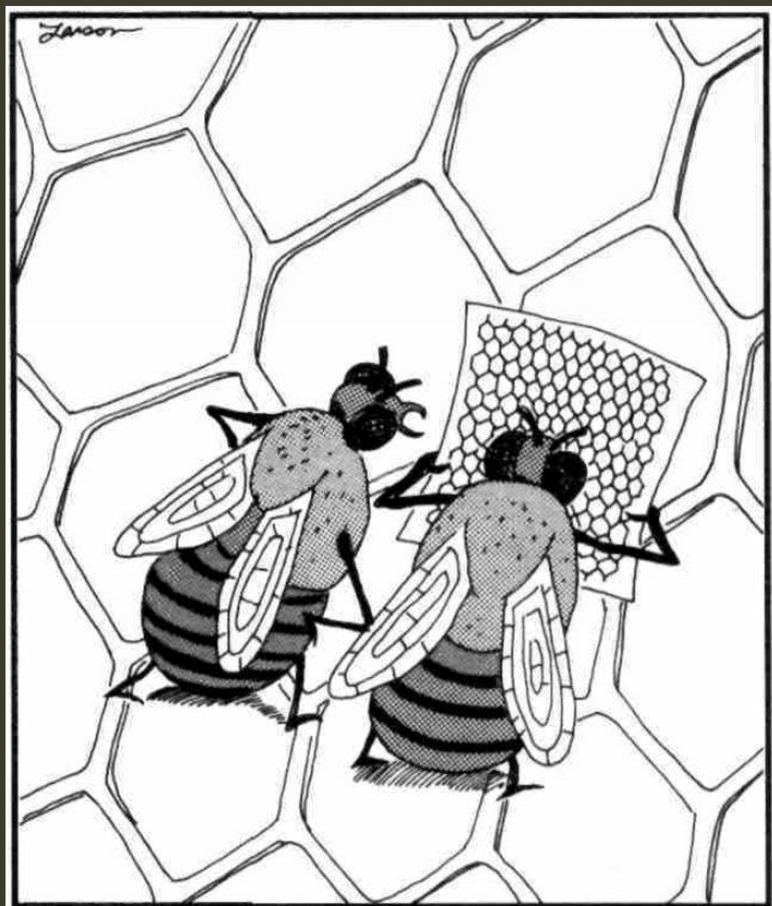



Source: Malloy 2012, Malloy and Dunning 2013

# Why the next 92 years are important





"Face it, Fred — you're lost!"

- Responses that appear negative at the stand level or in the short-term often are neutral (and sometimes positive) at the landscape level or over the long term
- Many existing studies have quantified stand level responses to forest management in time windows of 5-10 years
- Gaining an understanding on the HEE of changes across the landscape over time will provide novel insights guiding the management of populations

# Some HEE Publications



Community and Ecosystem Ecology

## Spatial Structure of Forest Lepidopteran Communities in Oak Hickory Forests of Indiana

KEITH S. SUMMERVILLE,[1,2] MIRANDA M. DUPONT,[1] ANDREW V. JOHNSON,[3] AND ROBB L. KREHBIEL[1]

Environ. Entomol. 37(5): 1224–1230 (2008)

*Ecological Applications*, 21(3), 2011, pp. 806–816


## Managing the forest for more than the trees: effects of experimental timber harvest on forest Lepidoptera

Keith S. Summerville[1]

*Department of Environmental Science and Policy, Drake University, Des Moines, Iowa 50311-4505 USA*

*Abstract.* Studies of the effects of timber harvest on forest insect communities have rarely

Landscape Ecol (2010) 25:1349–1362
DOI 10.1007/s10980-010-9499-5

RESEARCH ARTICLE

## Isolating spatial effects on beta diversity to inform forest landscape planning

**Jeffrey D. Holland**

Received: 29 March 2009 / Accepted: 11 June 2010 / Published online: 26 June 2010


**Abstract** Understanding the effects of landscapes on pest and non-pest species is necessary if regional landscape planning is to both control pests and conserve biodiversity. A first step is understanding of how both pests and non-pest species interact with the landscape configuration to determine the density of the two groups. While it is impossible to examine the occurrence and dispersal behavior of all species, different turnover rates in different species assemblages may offer general insights into responses of species assemblages. In this study I examine the distance decay of similarity of longhorned beetle assemblages in a large forest area in Indiana, USA, with minimal differences in habitat and few barriers to dispersal. Differences in beta diversity between groups are therefore likely due to dispersal distances. I found differences in turnover rates between species that decompose dead wood and those that attack

**Keywords** Beta diversity · Biodiversity · Cerambycidae · Conservation · Distance decay · Forested landscapes · Management · Pest species

**Introduction**

Conservation of the biodiversity of beneficial or benign species may depend on encouraging such species in managed landscapes (Banks 2004). At the same time, economic losses from pest species must be considered as these will often trump conservation efforts. It would be ideal to have land use guided by information on how to encourage beneficial native biodiversity while at the same time limiting losses to pest species. Longhorned beetles (Coleoptera: Cerambycidae) are an ideal taxon for studying the

Ecological Indicators 15 (2012) 188–197

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

ELSEVIER

## Improving selection of indicator species when detection is imperfect

Natasha A. Urban, Robert K. Swihart*, Melissa C. Malloy, John B. Dunning Jr.

*Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN 47907, USA*

ORNITOLOGIA NEOTROPICAL 23: 335–341, 2012


## CERULEAN WARBLER (*SETOPHAGA CERULEA*) RESPONSE TO CHANGES IN FOREST STRUCTURE IN INDIANA

**Kamal Islam, Jennifer Wagner, Ryan Dibala, Margaret MacNeil, Kyle Kaminski, & Lila (Prichard) Young**

Department of Biology, Ball State University, Muncie, IN 47306-0440, USA.
*E-mail:* kislam@bsu.edu

Am. Midl. Nat. (2013) 170:111–120

## Effects of Forest Treatments on Abundance and Spatial Characteristics of Cerulean Warbler Territories

KYLE J. KAMINSKI AND KAMAL ISLAM[1]

*Department of Biology, Ball State University, Muncie, Indiana 47306*

Abstract.—We examined effects of forest treatments on Cerulean Warbler relative abundance and spatial attributes of territories between pretreatment (2007–2008) and post treatment (2009–2010) years in Yellowwood and Morgan-Monroe state forests in southern Indiana. Three management units received uneven aged harvests (patch cuts), three units received even aged harvests (shelterwood and clearcut), and three units received no treatment (control). Cerulean Warblers occurred in greater abundance at study sites that received even aged harvests than in uneven aged harvested stands based on point - count surveys. Cerulean Warblers were attracted to areas with large canopy gaps resulting from even-aged harvests. Territory sizes were not significantly smaller after harvest treatments. Cerulean Warbler territories on harvested and control sites were clustered, closer to roads and streams, and on steeper slopes with an eastern aspect compared to random sites. Our relative abundance estimates suggested that Cerulean Warblers responded positively to some types of forest treatments during the 2 y post harvest period.

Introduction

Cerulean Warblers (*Setophaga cerulea*) are migratory passerines with a breeding range that extends across the midwestern and eastern deciduous forests of the United States and parts of southern Ontario and Quebec, Canada. In South America, they winter on the eastern slopes of the northern Andes Mountains at middle and lower elevations (500–1500 m) from Colombia to Peru and regions of Venezuela (Robbins *et al.*, 1992; Hamel, 2000). An annual

Am. Midl. Nat. 165:143–149

## A Survival Estimate of Midwestern Adult Eastern Box Turtles Using Radiotelemetry

ANDREA F. CURRYLOW[1]

*715 West State Street, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907*

AND

PATRICK A. ZOLLNER, BRIAN J. MACGOWAN AND ROD N. WILLIAMS

*195 Marstellar Street, Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana 47907*

OPEN ACCESS Freely available online PLoS one

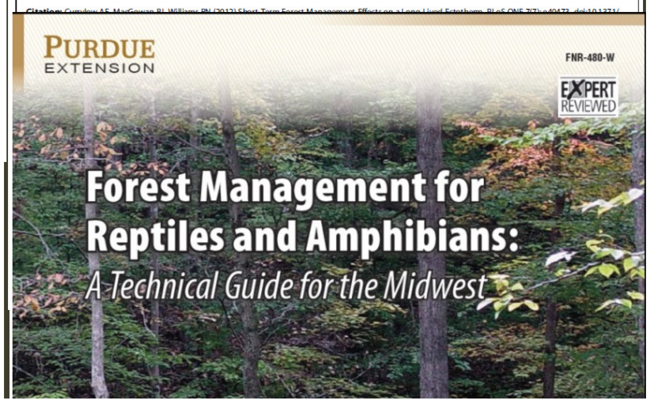
## Short-Term Forest Management Effects on a Long-Lived Ectotherm

**Andrea F. Currylow*, Brian J. MacGowan, Rod N. Williams**

Department of Forestry and Natural Resources, Purdue University, West Lafayette, Indiana, United States of America

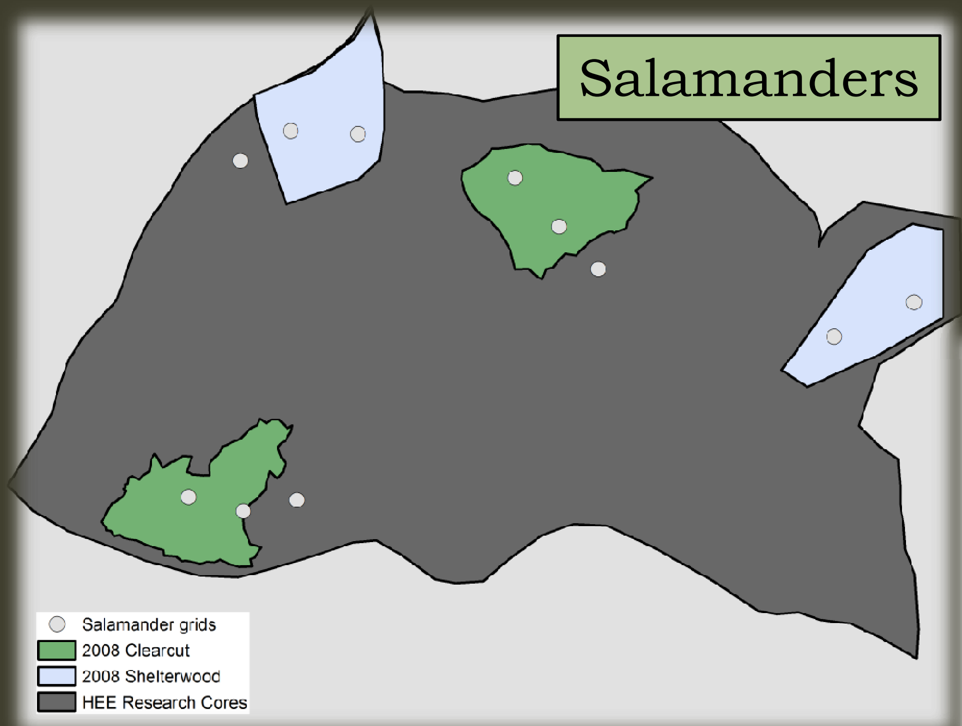
**Abstract**

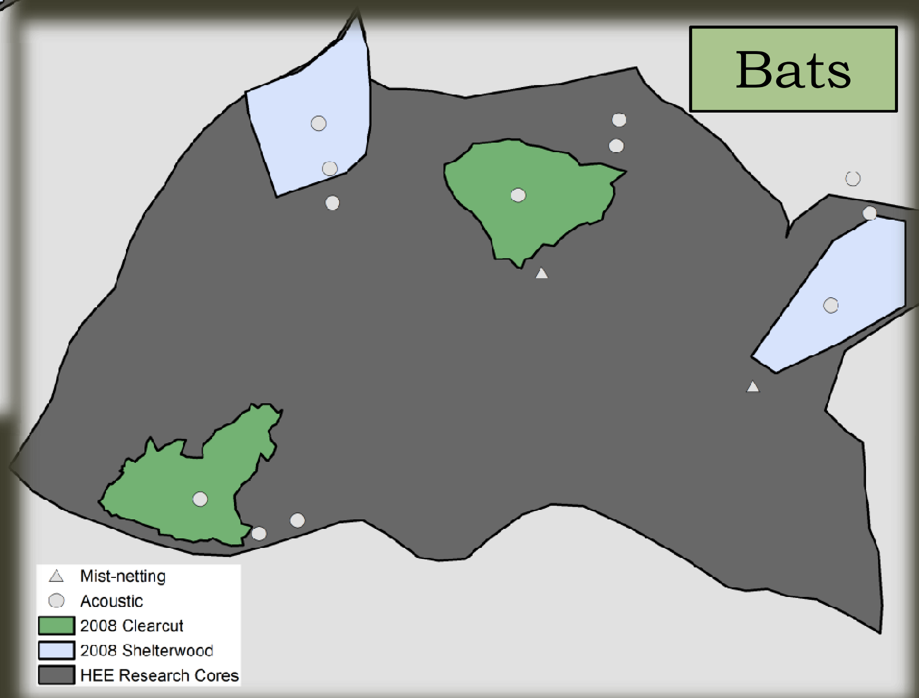
Timber harvesting has been shown to have both positive and negative effects on forest dwelling species. We examined the immediate effects of timber harvests (clearcuts and group selection openings) on ectotherm behavior, using the eastern box turtle as a model. We monitored the movement and thermal ecology of 50 adult box turtles using radiotelemetry from May–October for two years prior to, and two years following scheduled timber harvests in the Central Hardwoods Region of the U.S. Annual home ranges (7.45 ha, 100% MCP) did not differ in any year or in response to timber harvests, but were 33% larger than previous estimates (range 0.47–187.67 ha). Distance of daily movements decreased post-harvest (from 22 m±1.2 m to 15 m±0.9 m) whereas thermal optima increased (from 23±1°C to 25±1°C). Microclimatic conditions varied by habitat type, but monthly average temperatures were warmer in harvested areas by as much as 13°C. Animals that used harvest openings were exposed to extreme monthly average temperatures (~40°C). As a result, the animals made shorter and more frequent movements in and out of the harvest areas while maintaining 9% higher body temperatures. This experimental design coupled with radiotelemetry and behavioral observation of a wild ectotherm population prior to and in response to anthropogenic habitat alteration is the first of its kind. Our results indicate that even in a relatively contiguous forested landscape with small-scale timber harvests, there are local effects on the thermal ecology of ectotherms. Ultimately, the results of this research can benefit the conservation and management of temperature-dependent species by informing effects of timber management across landscapes amid changing climates.



# Stand Level Studies





# Landscape Level Studies